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Research on Mathematical Model for Deriving Standard Coefficients of Cultivated Land Consolidation

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Abstract

The cultivated land consolidation potential is based upon existing conditions of land utilization and local cultivated land consolidation standard. In order to keep cultivated land consolidation standard， factors including socio-economic demand for cultivated land, investments in cultivated land consolidation and the resulted environment improvements should be considered.

Keywords: cultivated land consolidation potential, standard coefficient of cultivated land consolidation, coefficient of per capita land, natural productivity potential

Introduction

Land consolidation has been put forward again as one important measure to achieve sustainable land use and dynamic balance of total arable land, and was given new meanings. Therefore, a nationwide land consolidation project has been launched, and in the process of compiling arable land's consolidation planning as well as feasibility study for land consolidation project, the calculation of arable land consolidation potential within the planning area or the extent of the project was taken as a basis for work. Based on the actual calculating work of the seminar to determine land consolidation potential in preparation of *Baofeng Land Development and Planning 2001 – 2010 project*, the recent land consolidation work, and the results of research done by other experts and scholars, this paper proposes a mathematical model to determine the standard coefficient in calculating process of land consolidation potential, so that researchers can scientifically calculate the land consolidation potential.

Problems in Status Quo and Potential Calculation of Land Consolidation

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At present days, the main purpose of land consolidation in many regions of China is to increase the effective area of cultivated land, which resulted in an effect that in many parts of China, the increment of cultivated area was taken as the sole criterion to appraise the potential of land consolidation, little attentions being paid to ecological and economic factors, as well as social needs and other factors. This practice conflicts with the modern sense of land consolidation in European countries focused on ecological protection and landscape construction. The hot points of land consolidation in foreign countries mainly focused on technical innovation, evaluation of land consolidation effects, and assessment of land consolidation benefits of the research. The farmland consolidation in Taiwan, makes the direct production increased by 9.6%, crop production increased by 25%, the concentration of land, plot area increased, the land utilization rate increased by 20%, labor and water were saved by 25% and 40% [1]. However, whether in foreign countries or in Taiwan, China, little research has been conducted on determination of standard coefficients for farmland consolidation.

In land consolidation, we have little experience to learn. Therefore, there is an inadequate practice in many places that the standard for basic farmland construction has superseded the standard for land consolidation. Most standardized farmland is still arable land waiting for land consolidation. If potential analysis is conducted by applying the basic farmland standard instead of land consolidation standard, the result obtained will not match with the actual potential, thus affecting the scientific planning of land consolidation, and the process of land consolidation project.

Analysis on Source and Content of Consolidation Potential for Arable Land

By comprehensive treatment and optimal placement of the farmland in the idle land, roads, ridges, abandoned ditches, ponds, and the idle land within villages, land consolidation can firstly minimize the site area of each land-use as far as possible, thus improve the efficiency of land use, and increase the area of available arable land. This process may produce different results in different regions. For example, in some areas the effective area of cultivated land may be increased while in other areas, it may be reduced, depending on the current land use state and the standards of local land consolidation. Secondly, through the land leveling and mergence， land consolidation can increase the effective area of cultivated land. The average household size of China's arable land is only 0.53-0.63 hm^2, far less than the size of family farms in Europe and the United States. It is even small than Japanese farm land scale (1.1 hm^2). In addition, because of the small scale of average household land, collocation of advantage and disadvantage plots, and piecemeal of plots, the actual scale of land operation in China is smaller than the land area scale, thus the average land per household is split into 9.7 pieces [2]. Thirdly, through the improvement of irrigation facilities, modification of irrigation and drainage channels, the water supply function is improved, and the production costs are reduced. Lastly, through village concentration infrastructure matching, and formation of forest networks, the ecological environment of farm or village is improved. As can be seen from the above analysis, cultivated land consolidation potential is just the comprehensive integration of the available arable land space's expansion, improvement of production capacity, production cost reduction, and improvement of ecological environment.

Land consolidation potential is a relative conception always based on a certain standard. Arable land consolidation potential depends on the status quo of local land use and standards for local land consolidation. Standards for land consolidation is the finished situation of cultivated land size, water conservancy facilities, forest network layout, field road's design, village location, and the scale of residential land, while the status quo of local land use is current situation in these aspects of land use[3]. Arable land is bound to be converted from current state into the designed state based on the standard of land consolidation. If either the status quo of local land utilization or standards for land consolidation is different, the land consolidation potential must be different. Arable land with different utilization ratios can achieve the same utilization ratio through land consolidation, while the increase in available space must be different. If the status quo of local land utilization and criteria for land consolidation are both altered, the potential for land consolidation may be the same.

Because of the various natural, regional, social, economic and technological conditions, the approach, direction, and characteristics of arable land utilization are also different. Therefore, the criteria for arable land consolidation are different between each other [4]. But what is common in different conditions is that the standards or criteria for arable land consolidation are closely related to socio-economic needs, objectives of land use, investment and natural factors such as the ecological environment.

Land Consolidation Potential under a Variety of Constraints

The consolidation potential for arable land can be divided into natural potential and actual potential. The former is defined as the extents to which the available space of cultivated land resource can be increased; land productivity can be improved; production costs can be lowered; the ecological environment can be improved; and relationship of property right can be adjusted through a series of administrative, economic, legal and technical measures in a period of time and under a certain productivity level. It doesn't take into account of the impact of economic and social development and human factors on land consolidation potential, deriving solely from the perspective of natural potential. However, if the natural potential for land consolidation is to be translated into reality, it is bound to be affected by investment, location, technology, infrastructure of the land itself. In short, the actual potential for arable land consolidation represents the reality of the possibility of land consolidation and the strength of investment demand during land consolidation process [5].

Land consolidation is an activity in adaption with the need of social and economic development. All sorts of national economic construction significantly demand the occupancy of fertile cultivated land, and the reverse development situation of population and land is grim while per capita cultivated land is declining across the country. Facing this situation, the health economic development must be maintained and the dynamic balance of cultivated land must be adhered. Secondly, land consolidation is a funded process demanding labor input, and a typical economic behavior. The reason why participants of land consolidation have a positive attitude is that they can obtain benefits through land consolidation activities. Meanwhile, the arable land consolidation potential is restricted by natural and ecological constraints. As a result, we must check the feasibility of consolidation activities in natural ecosystems, and whether consolidation activities would have regional adverse consequences. If land consolidation activities can only increase the area of cultivated land, but is not feasible in the ecology, it means that there is consolidation potential in this region.

Computational Procedure for Standard Coefficient of Arable Land Consolidation

Determination of Regional Area and Coefficient Computation for Ditch, Road, Drainage, Ridge and Sporadic Land. To be clear to the boundaries and area of land to be consolidated is a difficulty in reality for land consolidation. The Land Consolidation and Rehabilitation Center of Ministry of Land and Resources has issued *the provincial land consolidation planning standards* and *land consolidation planning standards at county level* and has not clearly defined zoning method. The standards abided to classify the consolidation zone for different regions are different [6]. The regional area of land consolidation is the existing cultivated land area in the year of 2000 minus the sum of slope arable lands with grade more than 25^0 and the area of lands whose grade is within the interval of 15^0-25^0 and is not appropriate for cultivation in administrative unit of town level. The coefficient of ditch, road, drainage, and tillage ridge in arable land is used to reflect and estimate the proportion of the sum of area of ditches, field roads, production road in total area of cultivated land area. It is actually the coefficient of invalid cultivated land. From the intuitive considerations, we still call it the coefficient of ditch, road, drainage, and tillage ridge [7].

The formula can be expressed as

$$Q_{ic}=(S_g+S_d+S_t+S_w+S_f)/S \qquad (2)$$

where Q_{ic} stands for the current coefficient of ditch, road, drainage, tillage ridge and sporadic plot, in %; S_g stands for the area of in-use and abandoned canals or ditches within the whole region to be consolidated, in hm^2; S_d stands for the road area within the region to be consolidated, in hm^2; S_t stands for the area of ridge within the region to be consolidated, in hm^2; S_w stands for the area of sporadic plots within the region to be consolidated, in hm^2; S_f stands for the area of abandoned lands within the region to be consolidated, in hm^2; and S stands for the computed total area of the region to be consolidated, in hm^2.

Determination of Standardized Coefficients of Land Consolidation Qis. Selecting adequate sampling and data-designing method, and set up reference farmland. In reference farmland, the standard coefficient of auxiliary productive land has close relationship with local topography and landform characteristics, farming systems, water resources, land-use design standards auxiliary productive land and other factors. The analysis is conducted on the basis of information from three main approaches. The first approach is to conduct planning and design typically for sub-regional land type in accordance with standards provided by national specifications of planning and design for land consolidation. The second is to conduct typical sampling within the county. Taking townships (town) for analysis unit, we select typical samples respectively in accordance with the general situation of contiguous land in each village. The total area of samples in each village should not be less than 2% to 5% of the arable land of the same type in the village. The overall land slopes is classified into three classes, including the kind less than 6^0, more than 6^0 and less than 15^0, and that more than 15^0 [8]. Linear features include ditches, roads, forest network; sporadic features include ridge, cemetery, scattered buildings, and other unused scattering land, the area of unused sporadic land patches being less than 5 hm^2 or 10 hm^2. The typical sampling area does not break the land of detailed investigation. Measure and compute the coefficient of auxiliary production land in districts with different socio-economic development levels and different types of landscape. The third approach is to collect the information of national and municipal land consolidation project in recent years. In practice of land consolidation, the general size of total area of land consolidation project in the hilly region should be 100-1000 hm^2, while that in plain should be 400-2000 hm^2. The area of single plot of land in hilly area should be greater than or equal to 40 hm^2, and that in plain should be greater than or equal to 60 hm^2. The implementation of land consolidation project is generally organized by townships, and concretely implemented by administrative level of villages. Therefore, ten villages are selected for this study and we obtained by calculation that the current coefficient Q_c of sampling plots equals to 5.15%.

Table 1. Results of investigation in current situation of land consolidation (in hm^2)

Administrative village	Land area to be consolidated	Cultivated land	Land not in use	Abandoned land	Ditch and canal	Country road	Percentage computed
Dongzhong, Chengguan town	29.46	28.24	0.60	0.00	0.51	0.11	4.14%
Wangzhuang, Shiqiao town	149.90	141.80	3.10	0.02	1.30	3.70	5.40%
Shiqiao, Shiqiao town	139.50	133.5	0.10	0.70	0.10	5.10	4.30%
Xiaolizhuang, Yangzhuang town	205.15	194.01	3.86	0.58	2.60	4.10	5.43%
Cuizhuang, Yangzhuang town	112.78	106.79	1.99	0.00	2.05	1.95	5.31%
Mazhuang, Lizhuang town	123.00	115.60	1.00	0.00	2.20	4.20	6.02%
Zhifang, Lizhuang town	43.50	41.20	1.10	0.00	0.40	0.80	5.29%
Dali, Zhangbaqiao town	63.37	60.25	1.35	0.89	0.53	0.35	4.92%
Dalingwang, Dayingzhen town	126.25	118.93	2.40	0.00	0.42	4.50	5.80%
Wugang, Shangjiuwu town	116.70	111.00	4.00	0.50	0.90	0.30	4.88%

Because the sampling plots investigated here are basic cultivated lands, the results given in the last column of the above table should not be taken as standardized coefficient of arable land consolidation. Therefore, the results have to be corrected. Thus we put forward the following formula

$$Q_{is}=Q_cK_1K_2K_3 \quad (3)$$

where K_1 stands for coefficient of per capita cultivated land, and K_1 = Mg / M; K_2 stands for coefficient of investment capacity; K_3 stands for natural and ecological coefficient; *Mg* stands for per capita area of cultivated land in land consolidation district; and *M* stands for provincial per capita area of cultivated land or national per capita area of arable land.

K_1 shows the demand of arable land by regional socio-economic development. The urgency of land consolidation is closely related to local per capita area of arable land and per capita land resource reserve. Small per capita area of cultivated land indicate the intensive contradiction between man and earth, high tension of land demand, and the urgency of land consolidation. The less the per capita area of arable land is, the stronger the need for arable land. K_2 indicates that land consolidation is a process demanding fund and labor input. Land Consolidation in China adopted a multi-channel fund raising system, i.e., a system of sharing investment and sharing benefit by national, local, and personal sectors. Local economic development situation largely determines the economic feasibility of the implementation of land consolidation. Therefore, it is necessary to consider the coefficient of investment capacity in classifying land consolidation potential [9]. K_3 shows that standard coefficient of land consolidation potential is affected by natural conditions and ecological factors, mainly including the terrain slope and requirements to ecological environment.

The per capita area of arable land in Baofeng county, Henan province is 0.088 hm^2,while the national per capita area of arable land is 0.093 hm^2 [10].

Here K_1= Mg / M = 0.95. The value of K_2 ranges from 0.8 to 1.2. The stronger the investment capacity is, the smaller is the value. K_3 is natural and ecological coefficient. It reflects natural and ecological conditions, mainly consisting of slope and ecological requirements. Based on situation of Baofeng county, we divide its arable land into two classifications, i.e., flat and slope. The former type encompasses land with gradient of 0^0-6^0 and we take K_3 = 1[11]. In interval of 6^0-15^0, K_3 increases by 0.01 for each 1^0 increment of gradient. It should be noted that the maximum gradient discussed here is 15^0.

In short, scientific, rational, and standard coefficient of land consolidation in Baofeng county is 4.9%. the land consolidation Baofeng standard coefficient of 4.9%. Take 5% as the standard coefficient of land consolidation, ie Q_{is} = 5%.

Calculation of Potential Value for Each Unit

The computational model for potential coefficient of cultivated land consolidation can be expressed as

$$Q_i=Q_{ic}-Q_{is} \quad (1)$$

where Q_i stands for potential coefficient of arable land's increment by land consolidation in the i-th land consolidating unit; Q_{ic} stands for the proportion of total area of current auxiliary production lands and sporadic type land against the whole area of the i-th consolidating unit; Q_{is} stands for standard coefficient of auxiliary production land against the standardized arable lands in the i-th consolidating unit after consolidation finished.

Taking administrative village as calculating unit, we further calculated the potential coefficient of arable land's increment by land consolidation for each analyzing unit according to the criteria already established to increase arable land consolidation potential coefficient Qi and the potential value for each unit to increase arable land. The formula can be expressed as

$$S=Q_i\times S \quad (4)$$

where ΔS stands for the area of arable land increment, in *ha.*

Conclusion

The establishment of standardized coefficients in land consolidation planning is a basic work , as well as the fundamental basis for compiling special planning and zoning for land consolidation. Therefore, it is necessary to conduct research on standard coefficients for arable land consolidation. Determination of standard coefficients of land consolidation is the key issue and technique for analysis and evaluation on land consolidation, and scientific standards must reflect how the potential of cultivated land consolidation is affected by characteristics of social, economic, ecological, technological and other external conditions. In land consolidation practices, we usually take the basic farmland, or basic rearranged farmland as standard coefficient for land consolidation, by which further calculate land consolidation potential. Nevertheless, some of the basic farmland still needs to be consolidated. Even if the former consolidated, relatively standard plots of land, whose area are too small, are still not able to adapt to modern agriculture operations so that need to be re-organized. We have re-planned the usual components in former finished small plots, such as field roads, canals, ridge, and etc. As a result, the land facility is boosted to achieve the requirements of modern farming. This model extracted from Baofeng's land development and planning project has been successfully applied in a number of situations. Compared with former methods taking basic farmland as standard for land consolidation, this model has decreased the standard coefficient (from 5.15% down to 5.0%), therefore enhanced the utilization ratio of land resource.

Even so, the potential and standard coefficients for land consolidation also still affected by many factors, as land use is multi-factorial, such as interactions of tillage, mechanization, and other relevant inputs. All these factors need to be further studied.

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